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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

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Plasma Etching Methods

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INVENTORS

Guy T. Blalock
David S. Becker
Kevin G. Donohoe

ATTORNEY'S DOCKET NO. MI22-776

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PLASMA ETCHING METHODS

TECHNICAL FIELD

This invention relates to plasma etching methods.

BACKGROUND OF THE INVENTION

Plasma etchers are commonly used in semiconductor wafer processing for fabrication of contact openings through insulating layers. A photoresist layer having contact opening patterns formed therethrough is typically formed over an insulative oxide layer, such as SiO_2 and doped SiO_2. An oxide etching gas, for example CF_4 is provided within the etcher and a plasma generated therefrom over the wafer or wafers being processed. The etching gas chemistry in combination with the plasma is ideally chosen to be highly selective to etch the insulating material through the photoresist openings in a highly anisotropic manner without appreciably etching the photoresist itself. A greater degree of anisotropy is typically obtained with such dry plasma etchings of contact openings than would otherwise occur with wet etching techniques.

One type of plasma etcher includes inductively coupled etching reactors. Such typically include an inductive plasma generating source coiled about or at the top of the reactor chamber and an electrostatic chuck within the chamber atop which one or more wafers being processed lies. The electrostatic chuck can be selectively biased as determined by the operator. Unfortunately when utilizing etching components having both carbon and fluorine, particularly in inductively

coupled etching reactors, a halocarbon polymer develops over much of the internal reactor sidewall surfaces. This polymer continually grows in thickness with successive processing. Due to instabilities in the polymer film, the films are prone to flaking causing particulate contamination. In addition, the build-up of these films can produce process instabilities which are desirably avoided.

The typical prior art process for cleaning this polymer material from the reactor employs a plasma etch utilizing O_2 as the etching gas. It is desirable that this clean occur at the conclusion of etching of the wafer while the wafer or wafers remain *in situ* within the reactor chamber. This both protects the electrostatic chuck (which is sensitive to particulate contamination) during the clean etch, and also maximizes throughput of the wafers being processed. An added benefit is obtained in that the oxygen plasma generated during the clean also has the effect of stripping the photoresist from the over the previously etched wafer.

However in the process of doing this reactor clean etch, there is an approximate 0.025 micron or greater loss in the lateral direction of the contact. In otherwords, the contact openings within the insulating layer are effectively widened from the opening dimensions as initially formed. This results in an inherent increase in the critical dimension of the circuitry design. As contact openings become smaller, it is not expected that the photolithography processing will be able to adjust in further increments of size to compensate for this critical dimension loss.

Accordingly, it would be desirable to develop plasma etching methods which can be used to minimize critical dimension loss of contact openings, and/or achieve suitable reactor cleaning to remove the polymer from the internal surfaces of the etching chamber. Although the invention was motivated from this perspective, the artisan will appreciate other possible uses with the invention only be limited by the accompanying claims appropriately interpreted in accordance with the Doctrine of Equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

Fig. 1 is a diagrammatic view of a plasma etcher utilized at one processing step in accordance with the invention.

Fig. 2 is a view of the Fig. 1 apparatus and wafer at a processing step subsequent to that depicted by Fig. 1.

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SUMMARY OF THE INVENTION

In but one aspect of the invention, a plasma etching method includes forming a polymer comprising carbon and a halogen over at least some internal surfaces of a plasma etch chamber. After forming the polymer, plasma etching is conducted using a gas which is effective to etch polymer from chamber internal surfaces. In one implementation, the gas has a hydrogen component effective to form a gaseous hydrogen halide from halogen liberated from the polymer. The hydrogen component is preferably one or more of H_2, NH_3 and CH_4. The conversion of the halogen, released from the clean into a hydrogen halide, renders it substantially ineffective in etching the substrate and thus reduces the critical dimension loss. In one implementation, the gas comprises a carbon component effective to getter the halogen from the etched polymer.

In another implementation, a plasma etching method includes positioning a semiconductor wafer on a wafer receiver within a plasma etch chamber. First plasma etching of material on the semiconductor wafer occurs with a gas comprising carbon and a halogen. A polymer comprising carbon and the halogen forms over at least some internal surfaces of the plasma etch chamber during the first plasma etching. After the first plasma etching and with the wafer on the wafer receiver, second plasma etching is conducted using a gas effective to etch polymer from chamber internal surfaces and getter halogen liberated from the polymer to restrict further etching of the material on the

semiconductor wafer during the second plasma etching. The first and second plasma etchings are ideally conducted at subatmospheric pressure with the wafer remaining *in situ* on the receiver intermediate the first and second etchings, and with the chamber maintained at some subatmospheric pressure at all time intermediate the first and second plasma etchings.

The halogen preferably comprises fluorine, chlorine or mixtures thereof. The gas at least during the second etching preferably includes oxygen, such as O_2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

It has been discovered that the polymer deposited on the internal walls of the etching chamber includes a significant concentration of fluorine. It is believed that the oxygen during the clean etching under plasma condition combines with the carbon and fluorine of the polymer liberated from the internal walls and forms carbon monoxide and carbon dioxide plus an activated or reactive fluorine species. Unfortunately, this liberated fluorine species is also apparently reactive with the silicon dioxide material on the wafer, which results in more etching of such material and the widening of the contact openings.

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Referring to Fig. 1, a plasma etching reactor is indicated generally with reference numeral 10. Such includes sidewalls 12 having internal surfaces 14. One or more gas inlets 16 and one or more gas outlets 18 are provided relative to etching chamber 12. A pump 20 is associated with outlet 18 for exhausting and establishing desired subatmospheric pressure conditions within chamber 12 during processing.

Plasma etching reactor 10 in the described embodiment is configured as an inductively coupled plasma etcher having a wafer receiver 22 within chamber 12 in the form of an electrostatic chuck. A biasing source 24 is electrically coupled with receiver 22. An inductive plasma inducing source 26 is diagrammatically shown externally at the top of chamber 10.

In accordance with the preferred embodiment, a semiconductor wafer 30 is positioned upon wafer receiver 22 within chamber 12. Wafer 30 has previously been processed to have a photoresist layer 32 formed on an insulative oxide layer (not specifically shown) formed on the outer surface of wafer 30. Photoresist layer 32 has contact opening patterns (not specifically shown) formed therethrough which ideally outwardly expose selected portions of the underlying insulative oxide layer.

A desired vacuum pressure is established and maintained within chamber 12 utilizing vacuum pump 20. An example chamber pressure is from about 30 mTorr to about 5 Torr. Inductively coupled source 26 and chuck 22 are appropriately biased to enable establishment

of a desired plasma within and immediately over wafer 30. An example power range for inductively coupled source 26 is from 100 watts to about 2,000 watts, with wafer receiver 22 being negatively biased to an example of 100 - 400 volts. Receiver 22 can have a temperature which is allowed to float, or otherwise be established and maintained at some range, for example from about -10°C to about 40°C.

Desired etching gases are injected to within chamber 12 through inlet 16, or other inlets, to provide a desired etching gas from which an etching plasma is formed immediately over wafer 30. Such gas can comprise, for example, carbon and a halogen. An exemplary gas would be CF_4. Etching is conducted for a selected time to etch contact openings within the insulative oxide material on semiconductor wafer 30 through the contact opening patterns formed within photoresist layer 32. Unfortunately, a polymer layer 40 comprising carbon and the halogen, in this example fluorine, forms over some of internal surfaces 14 of plasma etch chamber 12 during such etching. Such polymer can also form over photoresist layer 32 (not specifically shown). Such provides but one example of forming a polymer comprising carbon and a halogen over at least some internal surfaces of a plasma etch chamber.

Referring to Fig. 2, and at the conclusion of the first plasma etching and with wafer 30 on electrostatic chuck 22, chuck 22 is ideally provided at ground or floating potential and second plasma etching is conducted using a gas effective to etch polymer from chamber internal surfaces 14. The gas ideally has one or more components effective to

etch photoresist layer 32 from substrate 30 and polymer from chamber internal surfaces 14 (both being shown as removed in Fig. 2). Further, such one or more components of the gas are selected to be effective to getter halogen liberated from the polymer to restrict further etching of the insulative oxide or other previously etched material on the semiconductor wafer during the second plasma etching.

In one example, the gettering component comprises hydrogen which combines with the halogen during the second plasma etching to form a gaseous hydrogen halide which has a low reactivity with material of the semiconductor wafer, and accordingly is withdrawn from the reactor through outlet 18. Example hydrogen atom containing gases include NH_3, H_2, and CH_4. One example gas for providing the hydrogen component to the chamber is forming gas which consists essentially of N_2 at about 96% or greater and H_2 at about 4% or less, by volume.

In another example, the gettering component comprises a carbon compound. Examples include hydrocarbons, aldehydes (i.e., formaldehyde) and ketones (i.e., methyl ketone). Hydrocarbons will typically getter the halogen as a hydrogen halide. Where the carbon compound comprises a C-O bond which survives the processing, the halogen will typically be gettered as COA_x, where A is the etched halogen. One example carbon containing gettering compound having a C-O bond is CO, produced for example within the plasma from injecting CO_2 to within the reactor.

The gas also ideally comprises an additional oxygen component, such as O_2 or other material. Such facilitates etching of both polymer and photoresist over the substrate. Where the gas components comprise O_2 and a hydrogen atom containing component, the O_2 component and hydrogen atom containing component are preferably provided in the chamber during the second plasma etching at a volumetric ratio of at least 0.1:1 of O_2 to the hydrogen atom containing component. One reduction to practice example in a thirty-five liter high density plasma etcher included a feed for the second plasma etching of 60 sccm NH_3 and 1,000 ~~liters~~ sccm DB. 8/24/98 per minute of O_2. For a carbon containing compound, such is preferably provided at from about 5% to about 80% by volume of the oxygen/carbon compound mixture.

Plasma conditions within the chamber with respect to pressure and temperature and biasing power on induction source 26 can be the same as in the first etching, or different. Regardless, such first and second plasma etchings are ideally conducted at subatmospheric pressure where the wafer remains *in situ* on the electrostatic chuck intermediate the first and second etchings with the chamber being maintained at some subatmospheric pressure at all time intermediate the first and second plasma etchings.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means

herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

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